To:

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Subject: Proton Improvement Plan

Project Quarterly Summary FY15 Q3

Report #11 July 13, 2015

Project Milestones

There were 2 Linac scheduled milestones level 3.
Linac WBS Linac Notch System: *OPG module ready for installation* and *certify all 3-stages ready for installation*. These two milestones were pushed back by one and two months respectively. The reasons will be explained later on the section WBS 1.1.2.3 Linac Laser Notch.
The only Booster milestone was a level three Booster bias supply enclosure. This task was not completed due to shutdown effort requirements. However, the month delay for the final bias supply is not an issue. The completion of the Bias supply work is expected to be done well before needed.

L	WBS	Description	Baseline	Q2 Date	Q3 Date
3	1.02.03.01.02.05	Booster BPM System, Hdw. & Firmware Prototype Design Complete	12/22/14	5/1/15	7/1/15
2	1.02.03.02.01.14	Booster Long. Dampers Complete - boards installed & operational	10/30/14	5/15/15	7/2/15
3	1.01.02.03.03.20	Linac Notch (FA) Certify all three stages ready for installation	12/2/14	5/18/15	8/15/15
3	1.01.02.03.06.23	Linac Notch Beam shaping technology chosen	10/8/14	10/8/14	10/8/14
3	1.02.01.01.03	Specifications for Anode Power Supply Documented	10/15/14	11/26/14	11/26/14
4	1.01.05.02.01.10	Linac LCW System Complete	11/24/14	12/30/14	12/30/14
3	1.01.05.02.02.16	Complete 55 LCW Spare Syst	12/9/14	12/18/14	12/18/14
3	1.02.03.01.01.03	Booster BPM Specification Complete	12/8/14	7/2/15	7/2/15
3	1.01.02.03.05.33	Linac Notch Final Optical Cavity Certified	2/2/15	10/22/14	10/22/14
3	1.01.02.03.02.26	OPG module ready for installation	2/6/15	5/4/15	7/15/15
4	1.01.05.02.01.09	Complete Installation of New Dual Temp System	3/24/15	12/30/14	12/30/14
3	1.01.01.01.02.02	Prototype Klystron Final Assembly Drawings Complete	12/17/14	3/2/15	3/2/15
3	1.02.03.02.01.09	Specifications document for Booster longitudinal dampers complete	12/1/14	3/18/15	3/18/15
4	1.01.01.01.02.01	Final Cost Estimate for Linac Gallery Civil Construction	4/21/15	7/22/15	12/21/15
3	1.01.02.03.04.14	Linac Notch FSLA Operational on Bench - ready to install into OP	4/23/15	6/9/15	8/3/15
3	1.02.03.01.05.02	Booster BPM Production Procure/Assembly Complete	5/15/15	7/21/15	7/21/15
3	1.02.01.02.03.16	Finish program of gutting & assembling within Bias Supply enclosures	4/15/15	6/22/15	6/22/15
2	1.02.02.04.07	Commissioning & Beam Studies - Booster Cogging System Complete	4/14/15	4/15/15	4/15/15
4	1.01.02.03.06.33	Linac Notch Beam Shaping, Diag., Dump ready for installation	9/21/15	2/3/16	2/3/16

PIP Highlights by WBS Section

WBS 1.1 Linac

The vulnerabilities associated with the LINAC are the 200 MHz accelerating system, including power amplifier tubes and other associated systems such as the modulator; utilities for power distribution and vacuum systems; better need for reliable instrumentation along the Linac to improve beam transport and realistic machine model supported by real beam measurements. There are four largest elements of WBS Level 2 in Linac which are further subdivided at Level 3.

WBS 1.1.1 200 MHz RF Power System

The 200MHz RF Power System represents approximately 40% of the total scope of the PIP project. There are 3 level 4 elements which will be described below.

WBS 1.1.1.1 High Level RF

The klystron prototype development continues to make progress. Klystron design, details of the gun tank have been finalized between Fermi and CPI. The gun tank will include two arc detector fiber optic ports, a clear viewport on top, an oil level interlock, an oil temperature interlock, and an oil humidity interlock plus sensor. CPI was recently requested to include a current transformer and equipment for monitoring the HV in the gun tank, but is unable to due to space constraints in the tank. Fermilab has specified the HV cable length to be 20 feet.

Related with the klystron manufacturer status, all piece parts required for the seal-in assembly have been received. The cavity domes were the most difficult item to receive due to difficulties that the supplier had in final machining. The first and second braze using the dome has been completed successfully despite the large size and unique shape. Both cavities have completed their initial cold tests with the gap lengths and loop dimensions being chosen. An error in the placement of slots used for threaded rod supports was found before the cavities were welded, and the parts were re-machined with new slot locations. The parts have been returned to the clean room and are being final brazed before welding and the last cold test check. The 3rd cavity has been completed and is welded and ready to go on the klystron. A problem occurred during the brazing of the wall that connects the 4th and 5th cavities. The system warped. After repeated attempts to repair failed new parts were ordered. The last of the parts arrived at CPI at the end of the June and are being processed through the cleaning facility. A new strategy of brazing in multiple steps to limit risk and addition of supports in the assembly along with heat shields should make this second attempt go well. The most likely cause of the original failure was uneven heating of the part too quickly, with the outside diameter getting hotter than the inside diameter. This caused severe warping. The addition of a heat shield in the braze furnace along with a slower temperature ramp will alleviate this problem. Added supports will make the assembly more resistant to warping. This problem resulted in a delay of approximately one month. CPI is working to have the seal-in assembly completed by the end of July. This pushes the schedule right up to the contract limit.

The electron gun assembly is making very good progress. All assembly brazes have been completed. The cathode was received and the heater was tested with no problems. The next step is to stack the electron gun assemblies and weld.

WBS 1.1.1.2 Linac Modulator

AD/EE Support Design: Work is progressing well on developing a prototype modulator capable of replacing the present tube based design.

Cabinet construction: The cabinet has been assembled with cell support structures, wiring for the relay rack fans and power installed. Two air flow sensors have been built, tested and installed.

Cell construction: Additional corona shields to the holding rods on each cell were designed and manufactured. Finally, a written procedure was developed to guide the cell testing which began at the end of this quarter.

Charging Supply: Full power test run for the charging supply was performed this quarter. The team worked with the vendor on some minor modification which, despite being modest, was essential to facilitate replacement of the unit once installed in the relay rack. The additional 6 units were ordered at the end of the quarter with delivery date expected to next quarter.

Control System Relay rack: Significant progress on the control relay rack was accomplished this quarter. The wiring block diagram was finalized, including information of the interlock system. The backplane was ordered, received, stuffed with components and installed onto the rack. The rack has been wired for power and most of the supplementary electronics. The controls system PLC and touchscreen have been installed which will be used for interlocks and power supply control. The PLC has been programed with the appropriate interlocks code and was successful tested along with the interface box to the present interlock system.

Coding algorithm: A new code which dictates the modulator waveform shape and provide gradient control was developed and tested multiple times on an operation station during this quarter. Tests were performed on operation station LRF5 by connecting up the learning algorithms design for the Marx modulator and applying to the present modulator. During the testing the team was able to be achieve gradient regulation during beam to <<1%. Problems were noticed when one tried to run long and short beam pulses together. The system after learning the long beam pulse for an unknown reason was clearing the learning when a short pulse followed. Another version of the code was released to address this findings. Unfortunately was not successful. Further beam test will be required to find out more.

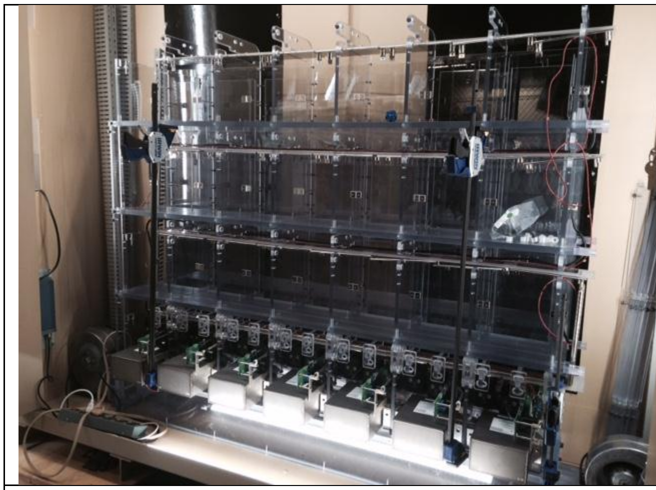

Figure 1: Linac Marx-Modulator Cabinet – showing cell shelving units and first row from the bottom populated with cells.

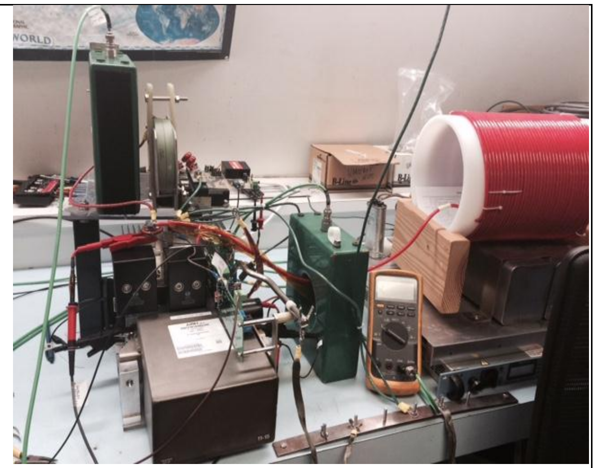

Figure 2: Linac Marx-Modulator cell testing setup. Every cell is tested prior being installed in the cabinet.

WBS 1.1.1.3 7835 Procurement

Linac Level-4 WBS completed (FY15-Q1).

WBS 1.1.2 Accelerator Physics

WBS 1.1.2.1 Simulations and Studies

Linac Level-4 WBS completed (FY15-Q1).

WBS 1.1.2.2 *Not Used*

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.1.2.3 Linac Notch Creation

Work continues with the development of the laser notch system. In the last report was mentioned that the 2W amplifier stopped working during tests creating too large of gaps in the 450 kHz burst laser pulses. The team and the company worked closely together to identified alternatives and implement solutions to address this issue, including adding extra protection to turn equipment off if either the seed pulses of keep alive disappear. The appropriate modifications were implemented and test/characterization and integration to the other components proceeded with additional difficulties encountered. While performing a test transmitting the laser from one fiber to another and observing the output on a power meter, the fiber connectors got damaged between the seed and tap coupler. The cause is not well isolated: it could have been caused by either a speck of dust landing on the delivery fiber's core or an over-amplified pulse from the upstream amplifier. The repair of these connectors have been carried on by the company at the end of this quarter.

Further work on the optical board layout to accommodate for mounting of the components with no interference among elements. A decision on the location of the viewport launch mirror was made which impacts the design of the transport tube.

Optical cavity modifications were complete and a new OC was built during this quarter. Among the changes are that the back of the mirror holders were removed so that one can see through the back; the adjuster springs and design was improved to make the adjustment tighter; the fixed mirror longitudinal adjuster was moved to the front, and finally, the most important modification, access holes for the adjustable mirror adjusters was made accessible from the outside of the cavity. The manufacturer of this piece was crucial to not slip as this is a shutdown installation task.

On another front, the interlock chassis box with the associated set of input/outputs was identified, designed, built and documented during this quarter. In addition, the group identified a PCI DAQ card to interface with LabView and ACNET to provide position and intensity data for local display.

Furthermore, the installation plans for the coming summer shutdown was formed. Electrical needs, cooling, slight modifications on the injector line were discussed and appropriate manpower was identified to carry on the tasks.

WBS 1.1.3 Instrumentation

WBS 1.1.3.1 Beam Position Monitors

First Linac Level-3 WBS completed (FY13-Q2).

WBS 1.1.4 *Not Used*

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WBS 1.1.5 Utilities

The Linac Utilities, such as power distribution, water and vacuum systems are composed of mostly 40 year-old equipment beyond its practical service life. There are three Level 4 elements in this WBS.

WBS 1.1.5.1 Power Distribution

Linac Level-4 WBS completed (FY14-Q4).

WBS 1.1.5.2 LCW distribution

Linac Level-4 WBS completed (FY15-Q1).

WBS 1.1.5.3 Vacuum System

Linac Level-4 WBS completed (FY14-Q4).

WBS 1.2 Booster

Part of the PIP effort for the Booster Accelerator is to address the increase proton beam flux that will be demanded by the Fermilab program in the upcoming years. The increased flux will be achieved by providing beam on more/all of the Booster cycles; certain equipment will increase from an average 7.5 Hz to 15Hz. Overheating of old components is a major concern; several Booster PIP tasks are to upgrade/refurbish equipment to run at 15 Hz. During the FY15Q3, we were able to test the Booster at 15 Hz.

The aging original equipment and infrastructure of the Booster are vulnerable due to obsolescence and increase wear due to the increase of flux. Some of the PIP effort is to replace these possible reliability problems.

WBS 1.2.1 RF

WBS 1.2.1.1 Anode Supply

The first anode supply has been built and tested with the exception of the final high powered test. The second anode supple sub-assemblies are being built. During the 2015 shutdown, the anode supplies will be installed.

WBS 1.2.1.2 Bias Supply

Eight retrofit bias supplies have been tested and installed. The ninth retrofit is complete and awaits testing. One more bias supply needs to undergo retrofitting.

WBS 1.2.1.3 *Not Used*

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.2.1.4 Cavity Test Stand

The cavity test stand task will not be done since there will be no benefit to PIP.

WBS 1.2.1.5 Cavity and Tuners Refurbishment

During this last quarter, we were able to install a 17^{th} cavity capable of 15 Hz which would allow full system checkout at 15 Hz. However, immediately a cavity-tuner set failed. In addition, another cavity-tuner set failed. There were similar problems when we were first started testing half the system at full rate.

Two previously failed refurbished cavity-tuner sets were reworked again. For the last week of the quarter, the RF system was run at 15 Hz. The testing of operating the RF system at 15 Hz will continue after the shutdown; this will include increasing the proton flux.

WBS 1.2.1.6 New Tuners

Previously, a high power test stand for ferrite cores showed that one of four different core sets (two different permeabilities from two vendors) was acceptable. The acceptable core samples have been implemented into a tuner and been certified. The tuner was installed on a re-furbished cavity; the cavity has been operation since FY14Q4. A purchase order for enough ferrite cores to build twenty tuners was placed. When shipments of the ferrite cores arrive, a through quality assurance tests are conducted; there have been no problems with ferrite cores.

Fermilab Technical Division is using the ferrite cores with other sub-assemblies to build new tuners. As the group gains experience building the new tuners, the process has become about three weeks to complete a tuner. Five tuners have been built and passed acceptance tests. Figure three below is one of

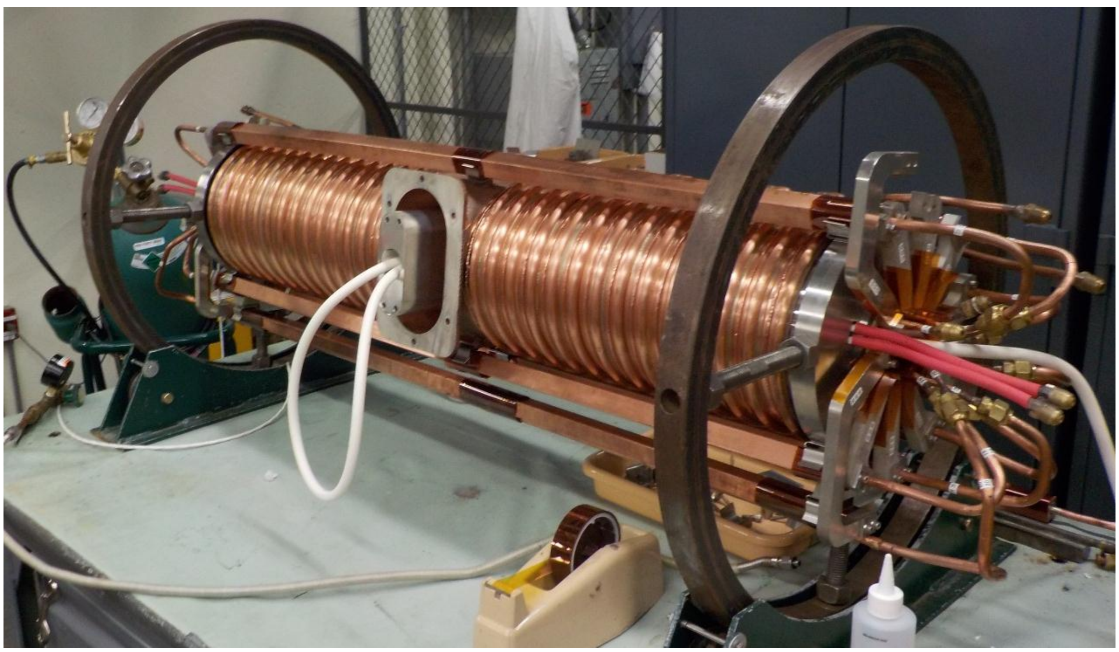

Figure 3 New tuner undergoing leak testing

the new tuners built by TD. Each one undergoes a series of tests before being installed on a cavity.

WBS 1.2.1.7 Replacement Cavities

Comparison of a model developed for the current Booster RF cavities and the temperature measurements taken as part of the refurbishment task continues. Further tests of cooling rates will be done to be compared with the simulation. A preliminary look into making small improvements to the cavity-tuner design is being done. Detailed temperature measurements were done during cavity and tuner set refurbishment certification (WBS 1.2.1.5); further measurements will be done during the next cavity tuner set certification.

The task has been renamed from new to replacement. Fermilab has recognized that any new/replacement cavities should work with PIP II and possible future rapid cycling synchrotron. Requirements satisfying now and for the future are being determined.

WBS 1.2.1.8 Cavity 1013

The cavity was put into operation in FY14Q4 and was operational during FY15Q1. There have been no problems with this reworked cavity. This task is considered complete.

WBS 1.2.1.9 Second Harmonic Cavity

The investigation of possible benefits of using a higher order harmonic cavity continues; in particular, for beam capture and transition crossing. The investigation is focused upon a perpendicular biased cavity. Work previously done at SSC and TRUIMF was our starting point. Modelling and simulations progress has led to improvement over the old designs. Garnet sample testing show that it is suitable for a perpendicular biased cavity. Parts are being orders and manufacture to build a partial mock-up which will be used for further testing for design and simulation validation.

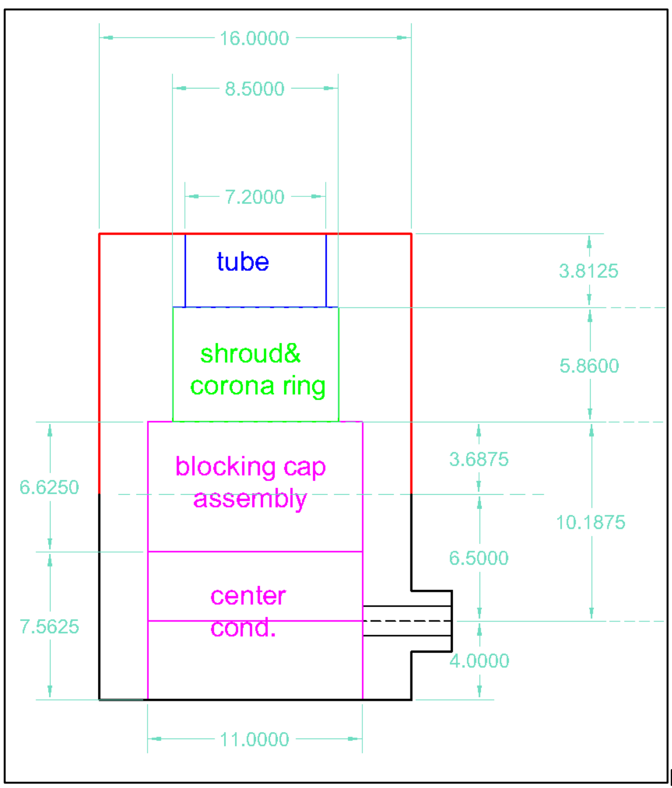

Figure 4 Perpendicular cavity PA assembly layout

WBS 1.2.1.10 Rework of Two Cavities

Although not new cavities, PIP has decided to reclaim two other cavities and rework them to be the 21st and 22nd Booster cavities (similar to the rework done for cavity 1013; WBS 1.2.1.8). Long lead time items are being procured. This work will commence after the refurbishment task (1.2.1.5) is complete. Tuners will be provided by work done by the New Tuner task (1.2.1.6).

WBS 1.2.1.11 Three New RF Stations

In addition, PIP will implement three additional RF stations to bring the total number of Booster RF stations to 22. This requires electrical work, water cooling work, assembly of power equipment and cable pulling. The 20th RF station is to be completed during the 2015 shutdown and the remaining two RF stations to be completed in the following shutdown. Detail planning for the 20th RF station is complete. For the other two stations, an initial conceptual layout has been done.

WBS 1.2.2 Accelerator Physics

WBS 1.2.2.1 Simulations and Studies

The people assign to the task of organizing, performing and analyzing beam studies has been consistent for the last few quarters. The main work is being done by an accelerator scientist in the Proton Source Department. There are several physicists from the Accelerator Physics Center also involved. The control programs for adjusting the lattice and tunes have been combined. The resulting application can adjust either the lattice or tune without affecting the other. Testing of this application is on-going and has to not affect operations.

The Booster was operational most of this quarter. Work is on-going to smooth the orbit to an ideal orbit (see WBS 1.2.2.2), measure the optics and adjust optics throughout the ramp cycle. A big part of this is to verify the Booster lattice by making beam measurements. Figure 5 below is an example of the beam chromaticity measurements compared to corrector settings.

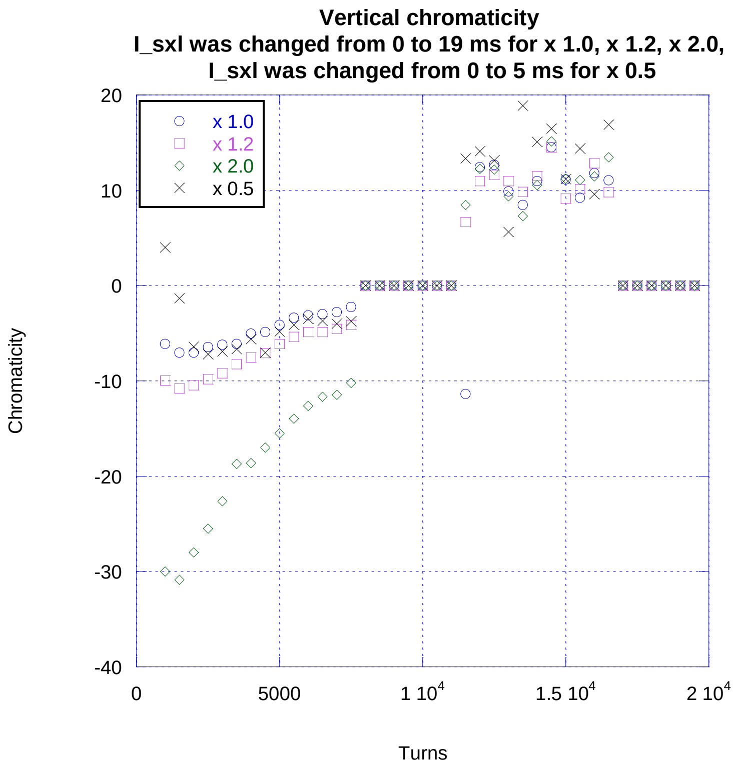

Figure 5 Verifying Booster lattice projections

WBS 1.2.2.2 Alignment and Aperture

Currently, no further magnets are scheduled to be moved. There are a few candidate magnets, but current simulation and beam studies (WBS 1.2.2.1) do not suggest that there will be noticeable improvement. The centers of the apertures have been designated as the ideal orbit (see WBS 1.2.2.1). We may return to this task in the future.

WBS 1.2.2.3 Booster Notcher

This task would be considered complete with the exception of some modified components are more activated than expected. We continue studies to understand.

WBS 1.2.2.4 Booster Cogging

Studies of the new cogging board and code were concluded this quarter. The cogging board was put into operation. This task is essential finished with the exception for interfacing with Linac laser notching system in FY16.

WBS 1.2.2.5 Booster Collimation

The collimation task is to control Booster beam loss after implementing the above notcher and cogging systems. A group has started studies of using existing collimation components. These studies include simulations, beam loss observations and exercising collimators movements.

WBS 1.2.2.6 Radiation Shielding

Beam studies concerning the beam loss profile and measurements of beam loss radiation through penetrations have been done. Simulation studies involve the effectiveness of the passive shielding, active detectors and radioactive source terms for penetrations are nearly complete.

A Total Loss Monitor (TLM) system of eight long detectors has been installed; each detector covers three Booster periods. The assembly, testing and installation of the needed electronics was completed during FY15Q2. Beam loss tests and measurements have continued. The analyses and write-up investigating beam loss as well as TLM responses continue. The TLM and radiation shielding assessment need to be concluded before much more proton flux can be attempted.

WBS 1.2.3 Instrumentation

WBS 1.2.3.1 Beam Position Monitors

The design work for the beam position monitor system is nearly complete and procurement has started.

WBS 1.2.3.2 Dampers

Studies were conducted which showed that the damper board and code work and will perform the needed function. Final programming will be done soon and the damper board will be become part of operations.

WBS 1.2.4 *Not Used*

Some WBS numbering is nonconsecutive at lower levels because of account closings and rearrangements after financial codes were initially established during the period of setting up PIP.

WBS 1.2.5 Utilities

WBS 1.2.5.1 Low Conductivity Water System

The task is done.

WBS 1.2.5.2 Power Distribution

The last power transformer has been manufactured. The transformer is identical to the two transformers previously purchased by PIP. Plans for installation during the FY14 shutdown were postponed when it was determined that the connection of this transformer is different than other replacements. A solution is ready to be implemented. The installation is now scheduled for the 2015 shutdown.

WBS 1.2.5.3 Vacuum System

The aged components will be replaced as opportunities present themselves with downtime of the Booster. Previously purchased vacuum equipment awaits opportunities for installation. During the shutdown, some vacuum work was done.

WBS 1.2.7 Solid State Upgrade

The task is done.

Booster Budget – Costs and Obligations Updates (FY15 Q2)

The FY15 third quarter had no significant budget changes. PIP to PIP II alignment discussions are still ongoing with plans to complete a document describing the necessary work to be released in FY15. However, PIP tasks as aligned to PIP II are understood and RLS adjustments are nearly complete.

PIP budget and labor through June of FY15 are provided below. A significant amount of the budget will be allocated for the new Linac modulators perpendicular cavity. The testing of the first modulator was required before completing the purchasing for the other 5 modulators. The modulator effort as noted in the task section above has continued but at a slowly rate than planned. The desire is to complete a power test into a dummy load before procuring more components. This modulator testing is expected to delay the M&S spending by a couple of weeks – pushing it close to end of fiscal year.

Table 1 PIP FY15 Q3 budget table

FY15 PIP OBL BUDGET K$ **	OBL BUDGET	YTD OBL	RIP	BUDGET BAL
M&S	6,334.5	1,594.5	5.9	4,734.1
Labor	5,465.5	4,476.1		989.5
FY15 Sums	11,800.0	6,070.6	5.9	5,723.6

The labor for this past quarter as shown in figure 6 below is very similar to the previous quarter and shows that PIP has been close on most of the requested labor. Like last quarter, the bump in mechanical from TD is due to the increased effort in building new Booster tuners. This will improve the refurbishment process and help improve uptime. Consistent labor has resulted in efficient and progressive PIP progress.

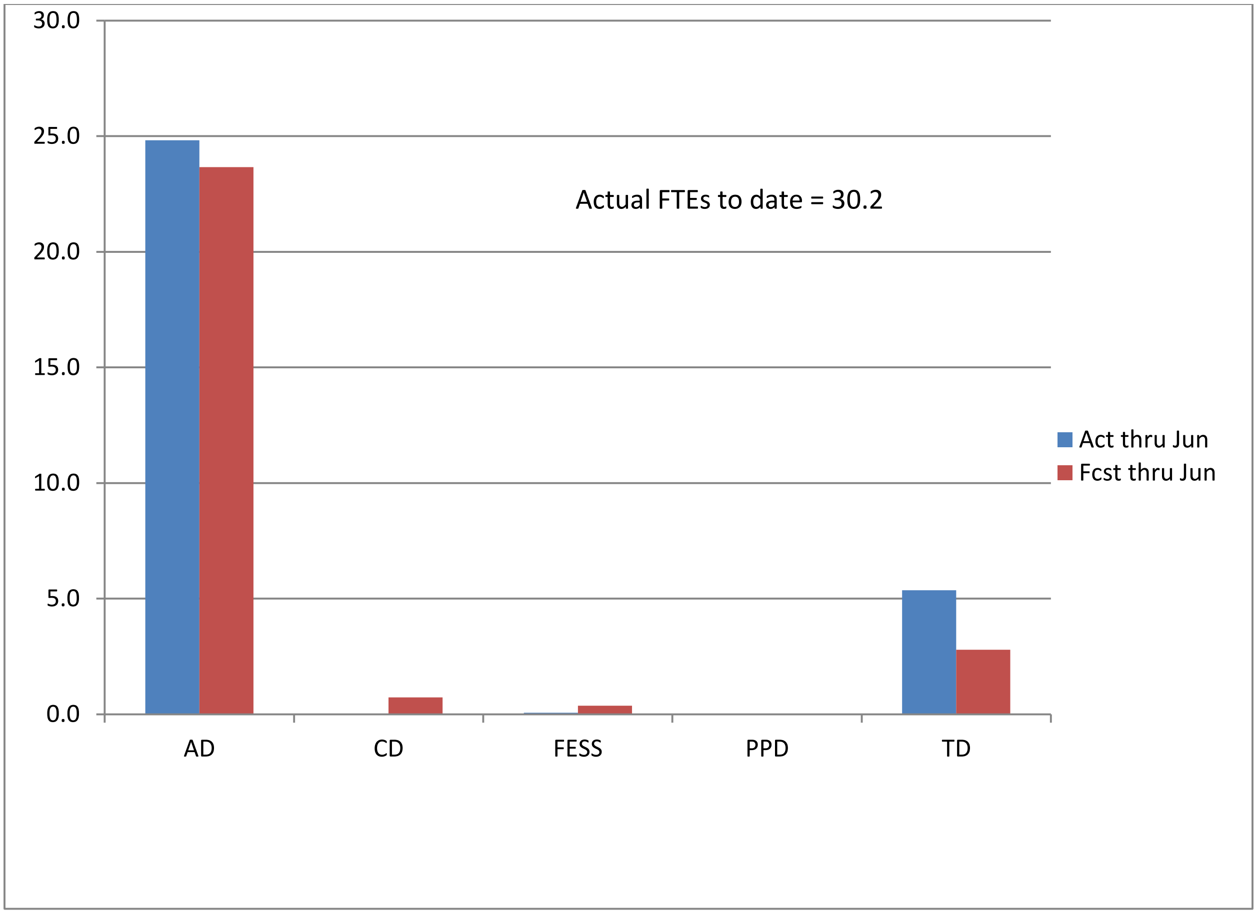

Figure 6 PIP labor to date